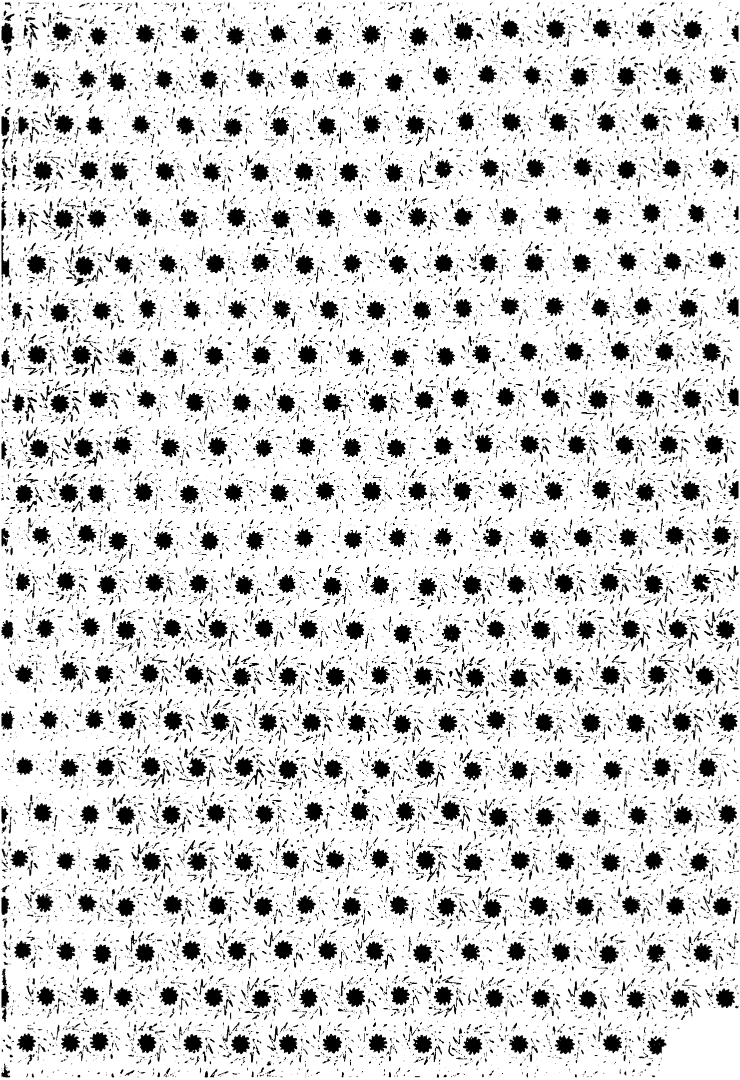

MANUAL

—OF— 90607

ICE-MAKING

—AND—

REFRIGERATING

MACHINES.

A TREATISE ON THE THEORY AND PRACTICE OF COLD-PRODUCTION BY MECHANICAL MEANS.

BY

ANDREW J. DIXON.

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PREFACE.

The rapid growth of the ice-making industry of late years, has brought with it a demand for literature pertaining to the various types of apparatus, and the different systems employed in the manufacture of artificial ice, as well as the mechanical refrigeration of buildings.

The books already upon the market, treating of this subject, require as a general thing, quite an extended knowledge of the laws relating to physics or thermo-dynamics, and therefore are not suited to the wants of the average seeker after information on the subject in question.

In the following pages, the author has endeavored, by eliminating all abstruse mathematical demonstrations, to present the subject in a clear, concise and attractive manner, so that the ordinary reader may become conversant with the principle features of the different processes involved, as well as the theory and practice of artificial ice-making and refrigeration.

A. J. DIXON.

INTRODUCTION.

During the past few years the manufacture of machinery for the purpose of producing ice by artificial means, and for the mechanical refrigeration of breweries, packing houses, chemical works, cold storage buildings, etc., has assumed vast proportions in the United States; and in view of the great advance of the industry, it is of advantage to the general public, as well as to those comtemplating the erection of an ice-making or refrigerating plant, and to those placed in charge of these plants, to gain a practical knowledge of the different types of apparatus used, and the different systems employed in the production of artificial ice and the mechanical refrigeration of buildings.

The rapid progress made in this branch of industry may be ascribed partly to the repeated failure of the ice-crops during preceeding years, and partly to the constantly increasing contamination of the water sources

in the vicinity of large cities from which the ice-crops are harvested. The great menance to the public health which the consumption of natural ice from these sources carries with it, has moved the sanitary boards of cities and health resorts to give the question of "hygienic" ice considerable attention, and has induced a growing demand among consumers for an article purer and better than that which nature affords.

In the cities and towns of the Southern States, ice-making by artificial means is regarded almost as a necessity; and in the large business centers of the North, ice factories are increasing with great rapidity, entering into direct competition with the natural-ice companies, and it is only a matter of a few years when the natural product will be crowded out of the market entirely.

The economical production of artificial ice is already an established fact, and it only remains for capital and enterprise to make the industry general.

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History of the Early Attempts at Artificial Cold Production.

Experiments were made by men of science, with a view of obtaining an artificial reduction of temperature, and thereby producing ice, as far back as the sixteenth century; and although those early attempts were of themselves crude and unprofitable, they combined to lead up to the perfected apparatus used to-day. Almost the first attempt in this direction of which we have any record, was that of an Italian physician and scientist, of the name of Blasius Villafranca, who, in the year 1550, discovered that temperatures could be reduced artificially by the dissolution of saltpetre in water. In the year 1607 Latinus Tancredus, another Italian, found that by a combination of snow with saltpetre, very low temperatures could be produced; and this discovery was the first of what are known as "frigorific mixtures," a well known example of which is the mixture of ice and common

salt used to-day in the manufacture of ice cream, and whereby a reduction of temperature of ten degrees Fahrenheit may be obtained. Later on experimenters discovered other frigorific mixtures, many of them, as in the case of that of Latinus Tancredus, employing snow or ice as an auxilliary to the chemicals used; and others employing simply a combination of chemicals, as muriatic acid, sulphuric acid, chloride of calcium, chloride of sodium or common salt, nitrate of ammonia, etc.

The first ice machine was patented in 1824 by Vallance. This apparatus consisted of shallow pans containing water, over which a current of dry, rarefied air was circulated. The vapors arising from the water were absorbed by the air, and as the process of evaporation continued, the heat necessary to produce these vapors being constantly abstracted from the main body of the water, lowered its temperature sufficiently to cause freezing. The aqueous vapors with which the air was laden after passing over the water, were absorbed by causing the current to flow into a vessel containing concentrated sulphuric

acid, and by this means the air was rendered fit for its purpose of again taking up new vapors from the water to be frozen. With this method the process of freezing was ren dered continuous.

Perkins, in 1834, contrived an apparatus for producing artificial cold by the evaporation of ether, and in this process the compression system was first inaugurated. The ether was allowed to flow into a cylindrical vessel containing tubes, where it was vaporized in consequence of the reduction of pressure caused by the suction of a pump at one stroke of the piston; and was compressed into another vessel, cooled by water, at the return stroke, and by this means the ether was restored to its liquid form and made fit for its purpose again.

The Ether Compression Machine of Prof. Twining.

The above attempts at artificial ice production were largely upon an experimental scale, and it is little less than forty years since ice was made in the United States for actual consumption. About the year 1850, Prof. Twining, of New Haven, a scientist of original and avanced thought, who had been for some time experimenting with sulphuric ether, with a view of devising some tangible process whereby ice could be produced in renumerative quantities, obtained his first patent in England on an ice machine. A patent was issued to him in the United States in 1853, and in 1855 he had a machine in operation at Cleveland, Ohio. Among other discoveries made during his early experiments, Prof. Twining found that by the vaporization of one pound of ether, he could produce 1.2 ponnds of ice from water at a temperature of 32° Fahr.; and in addition to this, that the ether could be reduced in temperature 28 degrees. Upon this and other data was based

the system employed in his Cleveland machine. In this apparatus he employed a double acting vacuum and compression pump of 8½ inches diameter, and 18 inches stroke of piston, and moving at the rate of 180 strokes per minute. A tubular condenser or "restorer" was used in which the ether was retained in liquid form by reason of the pressure induced by the compressing action of the pump, combined with the cooling effect of water at a comparatively low temperature. The liquid ether was permitted to flow through a pipe and valve, which regulated the amount required, to a part of the apparatus called the "cistern," in which on account of the reduced pressure existing therein owing to the sucking action of the pump, the ether would pass to its gaseous state, and by so doing abstract heat from the surrounding surface of the cistern. This cistern was made in such a manner that it comprised a number of cells open at their tops, and containing a liquid non-congealable except at extremely low temperatures. In this liquid were immersed iron moulds, also open at their tops, and filled with the water to be

frozen. After the water had completely changed to ice, the moulds were lifted from their cells, and subjected to a bath of tepid water, as is done to-day, in order to facilitate the removal of the ice-block.

Prof. Twining also discovered, while operating this machine, that by freezing the water at a comparatively high temperature, the resulting ice would possess the much desired quality of transparency, except for a small porous core in the center of the block, whereas, if the temperature was unduly low the result would be an opaque product. He furthermore found that by continuing the cooling process after the ice was formed, he could obtain a temperature of 26° Fahr. below zero, with an absolute evaporating pressure of 2.7 inches of mercury.

The Cleveland machine was designed with the intention of producing 2000 pounds of ice in 24 hours, but the highest actual product attained was about 1600 pounds, and this under disadvantages. It was operated occasionally during the interval between the years 1855 and 1857. The process employed in this machine, with the exception of the re-

frigerating agent used, is entirely identical with the compression system of the present day; and the credit of having brought this system to a state of comparative perfection, and of reaching the first practical results in the manufacture of artificial ice, belongs solely to Prof. Twining.

The Air-Compression Machine.

This type of refrigerating apparatus was first devised by Dr. John Gorrie, of New Orleans, who obtained a patent on a machine in 1851. Prior to this date, and upon the known principle that air during compression increases in temperature, and that while expanding, again decreases, Dr. Gorrie had conducted a number of experiments with a view of generating cold. From the fact that the increased temperature of air by reason of compression up to four or five atmospheres, amounts to several hundred degrees, he conjectured that by permitting the compressed air to expand after it had assumed the ordinary temperature of the surrounding atmosphere, in consequence of the cooling effect of water, its decrease in temperature below the normal would be in an inverse ratio to the original increase. Dr. Gorrie's experiments, demonstrating as they did, that artificial cold could be generated with the aid of no other agent than the atmosphere, and that chemicals could be entirely dispensed with, offered

great inducements to inventors, both in the United States and Europe, to continue their researches along this line. The laws relating to thermo-dynamics were not clearly defined at that time, however, and the dicoveries made in this branch of science during the years succeeding Gorrie's attemps, have deprived them of considerable value from a scientific standpoint. When it was generally understood that heat and mechanical duty are equivalent, and that the mechanical energy required to compress a stated quantity of air with a view of producing a certain amount of cold, greatly exceeded the work necessary when a volatile liquid was used, scientific men began to direct their researches along other channels.

Giffard's Compressed-Air Machine.

The plan of this machine is shown in Figure 0. (A) is a single-acting compressor pump, having a piston provided with two valves opening toward the top. Around the cylinder of this pump is a water jacket, which provides means for the circulation of a current of cold water. The piston of this pump is driven by the crank on the main shaft marked (*a*).

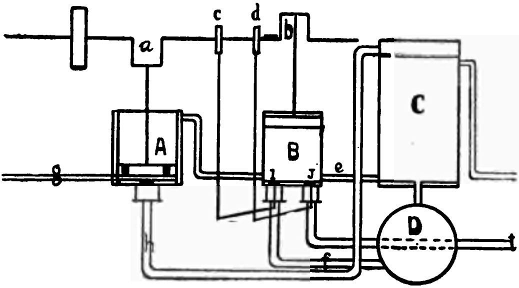


Fig. 0.

(B) is an expansion pump, also single acting, but provided with a solid piston a little smaller in diameter than the piston of pump

(A). The cylinder of this pump has two valves in the bottom, one opening upwards, and the other opening downward. These valves are opened and closed by means of the cams and levers marked (*c*) and (*d*), and operated by the driving shaft. The piston of this pump is driven by the crank marked (*b*).

(C) is a surface condenser, and is supplied through pipe (*e*) with a current of cold water from the envelope surrounding pump (A).

(D) is a reservoir made of wrought iron, and is brought into communication with the condenser by means of a short tube. It is also in connection with pump (B) by means of pipe (*f*).

The air at atmospheric pressure is drawn into pump (A) through (*g*), and compressed until it reaches the density of that in the reservoir, when it is allowed to flow into the condenser, through pipe (*h*), and from thence into the reservoir. During its course through these passages, the air parts with considerable of the sensible heat resulting from compression, and assumes a temperature but little above that of the surrounding air.

While this operation is going on the valve (*i*) opens, and an amount of air equal in weight to that which is pumped out at (A), is permitted to pass from the reservoir into the cylinder of (B), producing a definite amount of work. This valve then closes, and during the upward stroke the air expands, and the temperature is lowered. Upon the return or downward stroke of the piston the valve (*j*) opens, and permits the cold air to pass out through outlet (*t*).

The cams on the driving shaft are adjustable and arranged so as to regulate the opening and closing of valves (*i*) and (*s*). By shortening the period of admission into the pump (B), the pressure will be augmented in the reservoir; and the temperature of the air expelled will be lower. The amount of air flowing into (B) should be the same as that pumped into the reservoir from (A). By lengthening the period of admission, the pressure in the reservoir will decrease, and consequently the outflowing air will increase in temperature.

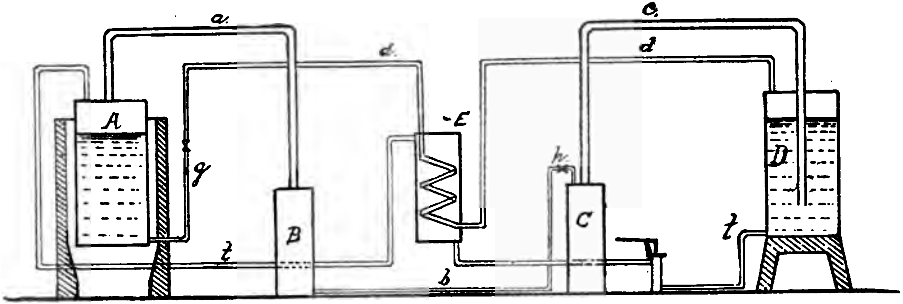


Fig. 1.

The Ammonia Absorbtion System.

This mode of refrigeration was first proposed by Ferdinand Carre, of France, in 1858, and was an entirely new and original departure from previous methods.

The manner of arranging the various parts of this apparatus, is illustrated in Figure 1. The portion of the machine marked (A) is called a generator, and contains an aqueous solution of ammonia in the proportion of 25 parts of ammonia to 75 parts of water. This generator is heated in some instances directly by a fire, and in others indirectly by steam pipes leading from a boiler. The ammonia solution in the generator being thus subjected to heat, the ammonia passes off in the form of a gas combined with aqueous vapor or steam, in the proportion of about 90 per cent of ammoniacal gas to 10 per cent of steam. In consequence of this distillation of the gas the pressure rises, and after passing through pipe (a) to the condenser (B) it becomes liquified, together with the steam, in consequence of the in-

creased pressure acting in combination with the current of cold water which cools the condenser externally. The liquified gas is now carried through the pipe (*b*) to the evaporating coils in the "cooler" or brine tank (C), where it again vaporizes, and in so doing absorbs heat from the substance to be cooled; the brine tank being so constructed as to utilize the cold thus generated. The valve (*h*) is provided to regulate the quantity of liquid ammonia required to produce the desired amount of refrigeration. The gas resulting from the evaporation of the ammonia in the cooler is led through pipe (*c*) to the absorption chamber (D), where it is taken up by a weak solution of ammonia contained therein, forming againa strong solution; the small quantity of aqueous vapor being carried along mechanically.

The ammonia solution is unequally saturated in the generator (A) under the influence of the heat applied; the stronger portion, of course, being uppermost. The weaker solution is conveyed through the pipe (*d*) into the absorption chamber (D), the flow being regulated by the valve (*g*); while the small

pump mounted upon the pipe (*f*) forces an equal quantity of strong solution from the absorber back to the generator, the pressure maintained therein being from 8 to 12 atmaspheres, whereas in the absorption chamber it is kept at about one atmosphere. While the solutions are passing through the cycle, there is an interchange of temperatures at (E), whereby the stronger liquid is heated before its arrival at the generator, and the weaker solution is cooled before being delivered to the absorber.

The amount of cold required depends upon the adjustment and regulation of the valves (*g*) and (*h*), and of the pump. These control the pressure under which the liquid is evaporated, and consequently the amount of refrigeration.

This type of apparatus has some advantages over the ammonia compression system in use at the present day; as, for example, its comparative cheapness of construction, and absence of complicated machinery; and again, it is deficient in several respects.

Substances Used for Generating Cold.

The cold-producing agent which has given the greatest satisfaction, and which is now in general use, is refined anhydrous ammonia liquid that has been purged of all impurities. This is only one of a number of volatile liquids that can be used, but none as yet experimented with have proven of such great adaptability for the requirements of refrigeration and ice-making. "Anhydrous" means free from water, but before an entirely pure liquid can be obtained, there are a great many other impurities besides water which must be eliminated.

As heretofore noted, the heat absorbing agent employed by Prof. Twining in his compression machine, was sulphuric ether; but owing to the extremely inflamable nature of this liquid. the high vacuum necessary to be maintained in order to insure its evaporation, thereby allowing air to enter the apparatus, and the obstacles in the way of perfect lubrication, it presented disadvantages necessary

to be overcome to secure efficient and reliable results.

So also, in the case of compressed air, which in the beginning possessed many seeming advantages. But it soon became evident, that owing to the inferior capacity of air for storing away heat, enormous quantities of this substance were required in the generation of cold; thus making necessary the use of compressing-pumps of great size, and consequently giving rise to an excessive amount of friction, and considerable loss of efficiency by leakage past the piston.

Among other substances for generating cold which have received attention from scientific investigators, may be mentioned carbonic acid, methylic ether, sulphurous oxide, nitrous oxide, methalymine, and chymogene.

Heat Absorbing Properties of Gases.

When a liquid passes into a gaseous state, or is converted into a vapor, it carries away from objects surrounding it a certain amount of heat, and its capacity to store away heat under these circumstances is called its *latent heat of evaporation.*

The unit of measure of this heat is called a *thermal unit*, and is equivalent to raising or lowering one pound of water one degree Fahrenheit.

For greater convenience the work expended in cooling is known as *negative heat*, in contradistinction to that done in heating, which is known as *positive heat.* The same laws are applicable to both.

The melting of one pound of ice requires the application of 142 units of heat, and the cooling work performed by the melting of four pounds of ice into water at 32 degrees Fah., is equivalent to the cooling effect produced by the evaporation of one pound of liquid ammonia.

Commercial anhydrous ammonia will boil

or evaporate at a temperature of 28½ degrees Fah. below zero, when exposed to atmospheric pressure. This is 240½ degrees lower than the boiling point of water subjected to the same condition.

From the above it will appear plain that if a vessel of liquid ammonia at a temperature below its point of evaporation, be thrust into water at 32 degrees, which is 60½ degrees above its boiling point, the result will be that the temperature of the ammonia will rise, and it will evaporate and boil away, and at the same time its vapor will absorb and carry away heat from the water and change it to ice. The effect is the same as though water at 60 degrees were poured into a vessel heated to a very high temperature, say 300 degrees Fahr. The water in this instance would immediately rise in temperature to the boiling point and pass off as steam, and the heat necessary to generate this steam would be taken from the vessel and it would be rendered cooler.

When it is remembered as a fact that the real or absolute zero of the negative thermometric scale is 461 degrees below Fahren-

heit's zero, or the zero of the thermometers in common use, it will be easy to comprehend that within this great range heat is merely a question of the relative difference of temperature of two or more bodies, and determines the gain or loss of temperature of one body when brought in contact with another, rather than the precise position in degrees the temperatures occupy upon the thermometric scale. The popular conception of heat is that it should be so hot as to burn, and it is a difficult matter for many persons to form any other idea than this. When two bodies of different degrees of temperature are brought in contact, the colder invariably absorbs the heat of the hotter until the temperatures of both are equal, and in the case of anhydrous ammonia whose boiling point is 28½° below zero, it will continue to boil, under atmospheric pressure, when placed in contact with any substance hotter than itself, and by absorbing the heat of that substance will render it continually cooler until it has been reduced to a temperature corresponding to the pressure underwhich the ammonia gas is generated; when this point is reached the ammonia ceases

evaporating and remains liquid.

Hydrogen, nitrogen, oxygen and other gases, including the compound forming the air itself are called the permanent gases; but they are no more permanent than other gases, being simply the vapors or gases of liquids whose points of evaporation are so low upon the scale of the thermometor that the natural heat of the earth is sufficient to cause them to remain inagaseous condition. This theory has been proved by numerous experiments made by eminent physicists, who have, by subjecting all known gases to an extreme degree of artificial cold and pressure, condensed them to a liquid. This method is the one in common use for liquifying gases, that is, to subject them to a constant pressure, and while under this pressure to rob them of their latent heat of evaporation by allowing cold water to flow over the condensing apparatus; or in the case of the gases above enumerated, to subject them to the most intense artificial cold that can be produced, and thus in connection with the pressure applied, to bring them to a liquid state.

In this connection it will be interesting to note the experiments of Dr. James Dewar, a Scotchman, and professor of chemistry in the Royal Institution of Great Britain. He has obtained the extreme degree of temperature of 210 degrees below zero centigrade—equal to 346 degrees below zero Fahr. and his method of doing so is as follows:–A double air compressor is used, into the outer chamber of which the professor introduces. by means of a pipe, liquid nitrous oxide gas, under a pressure of 1400 pounds per square inch. This liquid undergoes a rapid evaporation, and by so doing absorbs heat from the surface around the inner chamber, and lowers its temperature to 90 degrees below zero centigrade—equal to 130 degrees below zero Fahrenheit. A vacuum is maintained in the inner chamber thus cooled, and into it Dr. Dewar introduces liquid ethylene under a pressure of 1800 pounds, which in the process of vaporization reduces the temperature to 145 degrees below the centrigrade zero, or 229 degrees below zero Fahr. Through the inner chamber is passed a tube containing oxygen gas under a pressure of 750 pounds

per square inch; this gas liquifies at a temperature of 115 degrees below zero centigrade, and in a separate vessel from which the air is exhausted the professor collects the resulting liquid. Now to obtain the extreme temperature noted above, Dr. Dewar evaporated this liquid oxygen by diminishing the pressure, and when a temperature of 197.2 degrees below the centigrade zero is reached, or 322.9 degrees below zero Fahr., he obtains liquid air, which being subjected to pressure solidifies at 207 degrees below zero centigrade, or 340.6 degrees below zero Fahr. Ccntinuing his experiments, Prof. Dewar discovered that nitrogen liquifies at 14 degrees lower than oxygen, and under pressure it solidifies at 210 degrees below zero centigrade, or 346 degrees Fahrenheit. This latter is the lowest temperature which the doctor has yet reached, or rather, which he has measured.

It is in this manner that the ammonia gas is treated in a refrigerating apparatus; that is, the effect of the constant pressure of the compressor, combined with the water flowing on the condenser, is to liquify the gas in whatever quantity that may be desired. As

the boiling point of the liquid varies with the pressure, it will be seen that by regulating the temperature of the water flowing on the condenser so as to keep it a little below the boiling point at any pressure, the operator can regulate the degree of temperature required.

The above may not at first sight be readily understood, and an explanation may be necessary. For example: As is well known, when the pressure upon a liquid is increased, its boiling point is raised accordingly, and this being the case. it will be understood that liquid ammonia, whose boiling point under a pressure of one atmosphere, or nearly 15 pounds per square inch absolute pressure, is 28½ degrees, would have its point of evaporation raised or lowered according as the pressure is increased or diminished, and that by mechanical means, this pressure can be carried to such an extent as to raise the boiling point of ammonia to any desired temperature. It should be remembered that gas at a given pressure must have a temperature or boiling point to correspond with that pressure. For instance: The boiling point of water under

atmospheric pressure, or nearly 15 pounds per square inch, is 212 degrees Fahrenheit, and as a consequence the temperature of the gas or steam arising from it is likewise 212 degrees. If the pressure of the atmosphere be increased to 20 pounds absolute pressure, the temperature will be raised to 228 degrees. and so on.

It must be remembered that temperature and pressure are interrelated, or to express it differently, a saturated gas at a certain pressure has a temperature corresponding to that pressure, and this is the case with ammoniacal gas. If this ammoniacal gas, while under a specified uniform pressure or artificial atmosphere, be exhausted into a vessel made air-tight, and which is constantly receiving the cooling effect of water at a temperature somewhat lower than that due to the pressure of the gas, the result will be under these circumstances, that the vaporized ammonia will necessarily collapse and become condensed in the vessel, and return to its former liquid state.

The pressure to which the gas must be submitted so that its point of evaporation or

artificial atmosphere, will be raised high enough to preclude a possibility of its existing as a vapor when brought under the chilling effect of the condensing surfaces, depends altogether upon the temperature of the water available for use on the condenser.

As heretofore stated ammoniacal gas, which has been entirely deprived of moisture, is better adapted to the requirements of mechanical refrigeration than any other known substance. Its low point of evaporation avoids the necessity of a high vacuum on the expansion side of the machine, and thereby renders the use of large pumps unnecessary. At a pressure of from 15 to 20 pounds per square inch, the boiling point of this liquid is sufficiently low to produce the necessary cold, and at this pressure the gas has greater weight per cubic foot than at a lower pressure; and as it is the *weight* of gas circulated, and not *volume*, that determines the standard of refrigeration, it will be seen that one charge of a given pump will produce more cold than if the gas were circulated at a lower pressure.

A smaller quantity of ammonia is needed to produce a certain amount of cold than of any

other agent hitherto employed; and for the reason that its latent heat is higher than that of any other substances. It also possesses the commendable qualities of non-inflamability and non-explosiveness, and while it will attack copper and brass, iron and steel are entirely impervious to its corrosive action.

By a careful study of the foregoing remarks, the reader will understand the principle upon which all refrigerating and ice-making machinery used in modern practice is based.

The Simplest Form of Refrigerating Apparatus.

As appears from the foregoing remarks, artificial refrigeration is accomplished primarily by evaporation of some volatile liquid, which will boil at temperatures below the freezing point of water, that is 32 degrees Fahrenheit.

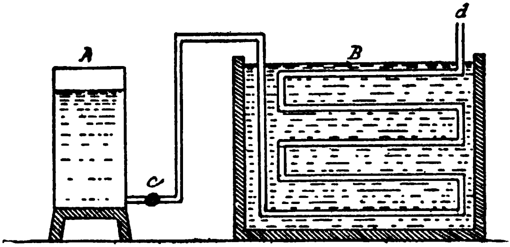


Fig. 2.

The simplest form of refrigerating apparatus that can be constructed is that shown in Figure 2; in which (A) is the tank containing the liquid ammonia under pressure; (B) is the evaporating coil placed in a congealer or tank filled with brine; and (C) is

the expansion valve which regulates the flow of liquid ammonia into the evaporating coil and controls the temperature.

With this apparatus the liquid ammonia after passing through the expansion valve, and being relieved of the pressure maintaned in the tank, would vaporize in the coil of pipe and convey away heat from the substance in the congealer, and after it had done its cooling work would pass off into the atmosphere at (D) and become wasted, so that the ammonia tank would have to be constantly receiviug fresh supplies of the liquid.

This process while of extreme simplicity, would be of tremendous expense, costing in in the neighborhood of $250 per ton refrigerating or ice-making capacity. On account of the high price of ammonia, and the difficulty of obtaining it in sufficient quantities, machinery has been devised for the purpose of reconverting the vaporized ammonia into a liquid, and using it over and over again.

The Ammonia Compression Machine.

This is the machine in general use at the present day, and the simplest form of a refrigerating device, based on this system, that can be used efficiently and economically is illustrated in Figure 3, and consists of three principle parts, which are: The evaporating coil (A) in which the ammonia is changed from a liquid to a gaseous state; a combined suction and compressor pump (B), which draws the ammonia vapor from the evaporator as fast as formed; a condenser or liquifier

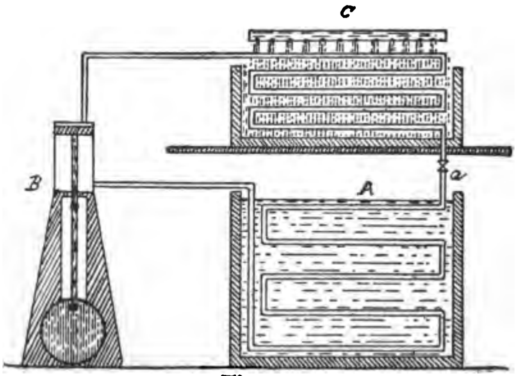


Fig. 3.

(C), which receives the gas as fast as discharged by the compressor pump, and in which under the combined influence of the pressure created by the pump, and the cold water flowing on the condenser, the vapor is reconverted into a liquid, and is ready to be used again in the evaporator.

After the apparatus has been supplied with the required amount of liquid ammonia, which for the sake of convenience wé will consider to be stored in the lower part of the condenser (C), an expansion valve, or small cock (a), which controls the flow of ammonia through the pipe leading from the condenser to the evaporator placed in a tank of brine, is partially opened, thereby permitting the fluid to flow into the evaporating coils. The heat from the surrounding substance is transmitted through the surface of the coils to the liquid ammonia contained therein ; and the temperature of the ammonia being brought to its boiling point at the pressure in the coils, which varies from 10 to 30 pounds above the atmosphere, it vaporizes the same as water in a steam boiler when subjected to the heat of the fire in the fur-

nace. As has been explained, the heat necessary to cause this evaporation is taken from the surrounding substance, and as a natural consequence it becomes cooler. The amount of positive heat taken up during this process, and made negative, is proportioned to the pounds of liquid ammonia evaporated.

The amount of mechanical cold desired can be easily regulated, being entirely under control of the expansion valve between the condenser and evaporator coils. When the gas begins to form in the evaporator, the suction of the pump (B) carries it away as fast as generated, and discharges it into the condenser under a pressure sufficient to produce condensation; this pressure being usually from 125 to 175 pounds per square inch. The gas thus becomes liquid again, and can be used over and over; the process of evaporation and re-condensation going on continually so long as the compressor pump is kept in motion.

The process of evaporation of the ammonia liquid in the evaporator coils may be likened to the action of water in a steam boiler. The heat of the salt brine, or of the atmos-

phere, corresponding to the heat of the fire in the furnace of the boiler. In both instances the liquid in evaporating carries away heat from the surface with which it is in contact, and in the case of the boiler new heat must be continually applied to the shell in order to continue the generation of steam. In the case of the evaporator coils, the surrounding surfaces will continue to become cooler until their temperature corresponds to the temperature of the ammonia at the pressure under which it is evaporated.

Two methods are employed to utilize the cold thus produced by mechanical means. One is called the *Brine System*, and the other is known as the *Direct Expansion System*. The latter is much to be preferred to the former, inasmuch as it does away with a great deal of superfluous apparatus, and also on the score of tidiness. This refers to the refrigeration of buildings as ice-making without the use of brine is impracticable.

The Brine System.

In the Brine System of utilizing artificial cold, the evaporating coils are placed in a tank, called the brine tank or congealer, as (B) in Fig. 2, which is filled with strong salt brine. a non-freezing liquid. Salt, as is well known, will not freeze at temperatures above zero, and for this reason it is well adapted for its purpose in mechanical refrigeration.

The expansion or evaporation of the ammonia in the coils, as heretofore explained, conveys away the heat from the brine, bringing it to a low degree of temperature, which is regulated according to requirements, by the gas-expansion valve.

When the brine has become chilled and is of the temperature desired, it is pumped out of the tank and through coils of pipe arranged along the sides und ceilings of the rooms to be refrigerated. In this respect the process is analagous to heating apartments by means of steam pipes.

As a natural consequence, the cold brine

in its passage through the pipes, becomes warmer by absorbing the heat of the rooms, and must be returned to the brine tank to be again cooled by the evaporating coils, when it is again pumped through the cooling pipes; the operation forming a complete cycle, and being continuous,

The Direct Expansion System.

In this method the evaporating coils are placed directly in the apartments to be cooled, instead of being placed in brine tanks. The ammonia is expanded or evaporated by absorbing the heat of the air in the rooms to be refrigerated, and the use of an evaporating tank is dispensed with.

The Compressor Pump.

The compressor pump is by far the most important detail of a refrigerating machine, as upon the perfect performance of its work depends, to a great extent, the efficient and reliable performance of the entire apparatus.

Compressor pumps are made either single-acting or double-acting; with a single-acting compressor, the gas from the evaporating coils enters the pump at the bottom while the piston is making its upward stroke; and upon the return, or downward stroke, it passes to the upper side of the piston through a valve placed in the piston, and so arranged as to open by pressure on its lower side; and at the same time a valve placed in the gas inlet to the pump is closed. The discharge valve is placed at the top of the pump, and by the compressing action of the piston on its upward stroke, opens, and allows the compressed gas to pass through into the condenser, closing again on the downward stroke of the piston, by reason of the pressure on its upper side. With this pump the work of compres-

sion is performed only on the upward stroke.

With a double-acting compressor, the gas is drawn into the pump and compressed at both strokes of the piston, two suction-valves and two discharge-valves being provided; the valve in the piston being dispensed with. The great difficulty with this class of pumps, has been the impracticability of employing an arrangement of outlet and inlet valves to overcome the large clearance spaces at each end of the stroke. But by a system of oil circulation employed by some manufacturers, these waste spaces are filled with a sufficient quantity of oil to preclude the possibility of any gas remaining after the piston has completed its stroke. This oil circulating system also has the advantage of effectually sealing the stuffing-box, piston, and the suction and discharge valves, as well as to rob the gas of considerable of its heat during compression.

Inasmuch as the same moving parts are required to operate a single-acting compressor, and as the amount of frictien to be overcome is the same in either case, it is apparent that a double-acting compressor is more advantageous; because one double-acting pump will

perform the same amount of work in handling the gas, as two single-acting machines of the same diameter and stroke of piston.

Figure 4 represents the single-acting vertical gas-compressor màde by the DeLaVergne Refrigerating Machine Company. This pump has a valved piston and valved diaphragm. The gas enters the pump from the return main through the large opening on the left-hand side near the bottom of the pump, on the up stroke of the piston. On the return stroke, the valve in the large gas inlet closes, and the gas in the cylinder passes to the upper side of the piston through the valve in the piston, which opens as soon as the valve in the gas inlet closes.

The lubricant for cooling the pump, and sealing its valve and piston-rod, is injected through the small aperture at the bottom and left side of the pump during the return stroke of the piston; therefore it will be observed that the cylinder is fully charged with gas before the introduction of the lubricant, and that the lubricant does not occupy any space to the exclusion of gas.

As the piston descends it becomes sub-

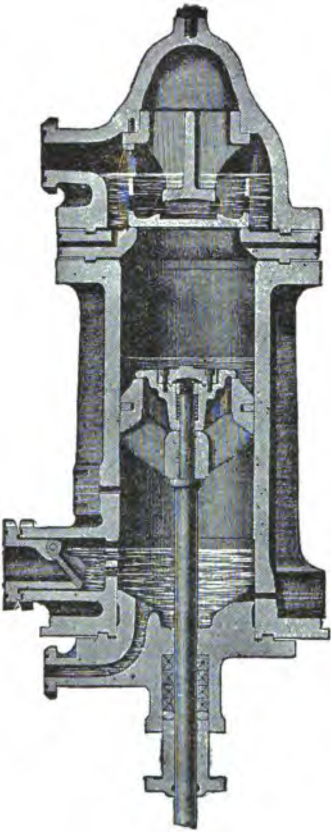


Fig. 4.

merged in the lubricant collected in the bottom of the cylinder, and a small quantity of it passes through the open valve to the upper side of the piston, and effectually seals the piston and prevents a slippage of gas past it during its upward stroke.

A sufficient body of the lubricant is introduced to the upper side of the piston to enable it to drive out all the gas, and, with it, a portion of the lubricant which passes through the diaphragm valve and which seals said valve upon the return of the piston.

The piston-rod is continually liquid-sealed by the remaining lubricant surrounding it.

The gas is discharged through the outlet on the left hand side at the top of the pump.

It will be observed that the piston is at all times thoroughly lubricated, and the valves holding the gas are sealed under a pressure greater than that of the atmosphere, giving no opportunity for wear or a slippage of gas past the piston or through the stuffing-box.

Figure 5 represents the double-acting compressor used by the same company. At the lower end of this pump there are two discharge valves placed on the side, one above

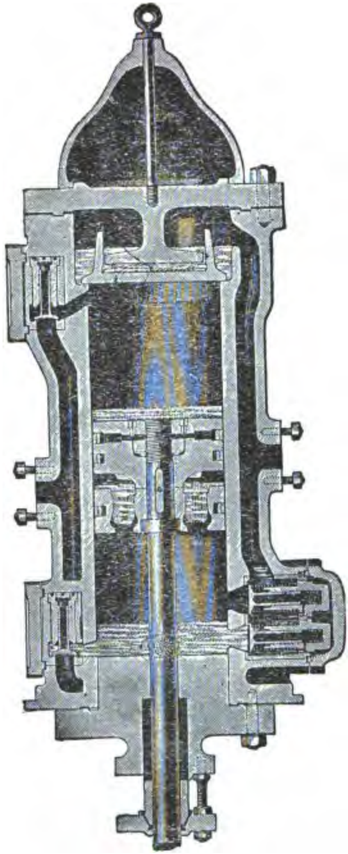


Fig. 5.

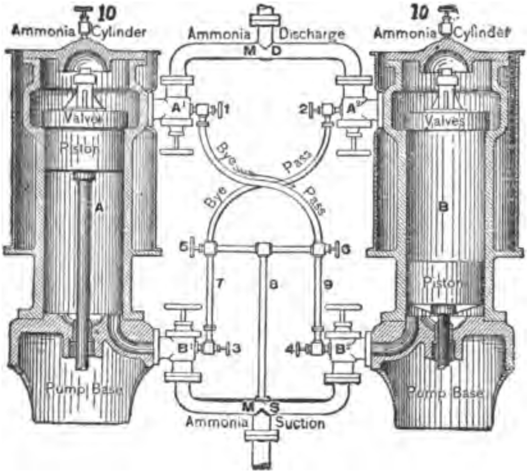
the other. On the down stroke either of the valves or both may open until the piston covers the upper one, when only the lower one is open to the condenser. In the further course of the piston, and as soon as the lower valve is also closed, the upper one is in communication with an annular chamber contained in the piston. This chamber has valves in its bottom, which open into it as soon as all other outlets from the lower side of the piston are closed (they open a little harder than the discharge-valves on the side), and now the gas will all go out through the piston; and after the gas the oil will follow, thus permitting no gas to remain on the lower side after the completion of the down stroke. It will be seen that in this manner the very important oil-system of the single-acting machine is retained, and that the lower side of the pump works as well as the upper, while the oil effectually seals the stuffing-box in spite of the higher pressure on it at the end of the down stroke.

The Bye Pass.

Figure 6 represents the "Bye Pass" used in connection with the "Eclipse" Refrigerating Machine. The usual method in vogue when any part of the apparatus is taken apart for examination, is to break a joint and allow the ammonia to escape before the part can be reached, thus wasting it; and this at times, in close rooms adjacent to fire, is somewhat dangerous. By providing a "Bye Pass", located on the pump platforms, the engineer is enabled to exhaust the ammonia from any part of the system, stop-valves being furnished to insolate every part, and store the ammonia in any other part temporarily until the repairs or examinations are made.

The bye pass is also used for exhausting the pumps themselves before the heads are taken off for examination. By means of its peculiar arrangement of pipes and valves the engineer is enabled to reverse the action of the compressor and pump the ammonia from the condenser, storing it in the brine tank.

In each case, after the examination of any



A, B, Ammonia Pumps
A₁, A₂, Discharge Stop Valves
B₁, B₂ Suction Stop Valves
1, 2, 3, 4, 5, 6 Bye Pass Valves
M, D, Main Discharge Pipe
M, S, Main Suction Pipe
7, 8. 9, Bye Pass Pipes
10 Purging Valves

Fig. 6.

part, the air can be exhausted therefrom, and the charge of ammonia reintroduced without the admixture of air.

The operation of the bye pass may be understood from the following description:

(A, B,) compressor pumps; (A^1, A^2.) main discharge stop-valves (B^1, B^2,) main suction stop-valves; (1, 2, 3, 4, 5, 6,) bye pass valves; (M, D,) main discharge pipe; (M, S,) main suction pipe; (7, 8, 9,) bye pass pipes.

To exhaust gas from pump (*B*,) all bye pass valves closed begin with; close main stop-valve (B^1, B^2,) and (A^2,); open bye pass valves 2 and 3; by running the pump slowly the contents of pump (B) can be exhausted; then shut valve 4 and remove bonnet. After closing bonnet, air can be removed same way, previously shutting main stop-valve (A_1) and expelling the air through purging valves (10) on pump-head; close all the bye pass valves when done and open main stop-valve.

To exhaust pump (*A*), proceed in the same manner, using the opposite set of valves.

To equalize pressure between Condenser and Brine Tanks, open stop-valve (A^1,) or (A^2) and bye pass valves 1 and 2, also 5 and 6, thus

forming a passage direct from main discharge to main suction pipes.

To exhaust Condenser and store gas in Brine Tank, All valves closed to begin with. Open stop-valve (A^1,)on pump A, bye pass valves 1 and 4, opening communication to pump suction (B), expel gas by opening bye pass valves 2 and 5, thus discharging into main suction pipes. Run pumps slowly. By using opposite set of valves, either pump may be used, the *modus operandi* being simply that one pump is used to exhaust the gas through the bye pass from the discharge, while the other forces it through the other half of bye pass into the suction pipe.

Except when in use all bye pass valves are kept closed.

The Condenser.

The second process in the cycle of operations previously mentioned is that of condensation, whereby the heat is abstracted from the compressed gas. As has been heretofore explained, when a gas is contracted in volume by compression its heat is augmented, and before it can be liquified it must be robbed of this heat by some cooling medium.

By investigating the relations existing among boiling points and pressures, it will be understood that the condenser is a practical application of a simple natural law.

Water at as low a temperature as can be obtained without undue expense, is the cooling medium generally employed. In an ice-making plant this water should be as free as possible from inpurities, so that after having performed its cooling work, it may be utilized for other purposes.

When possible, water from springs or deep wells is to be preferred to that from other sources, for the reason that it is generally much colder than surface water, and conse-

quently much less is required to produce the necessary effect. It is also to be commended on the score of economy, since the colder the water used for the purpose of condensation, the less power it requires in compressing the gas. Water obtained from sources below the surface has a nearly constant temperature of about 55 degrees the year round; while that from ponds and streams may vary from 32 degrees in winter to 95 degrees in summer.

Condensers are generally made in two forms; one consisting of a coil of pipe submerged in a tank of flowing water which absorbs the heat of the gas circulating in the coil; and the other of a vertical coil having a perforated gutter above it from which the cooling water issues in fine sprays, as shown in Fig. 3.

If the water used for cooling is muddy and liable to deposit a coating on the pipe, the latter method is preferable to the former; but if economy of space is a matter to be considered in the erection of a plant, the submerged coil is better adapted on account of its compact form.

The Different Systems Employed in Making Ice.

Tho art of making ice by artificial means may be devided into two general systems, as follows: The application of a machine for freezing the water by direct expansion, as is done in refrigerating plants in the one, and by the use of brine for the purpose of freezing in the other.

Freezing by the first process, although far preferable to the latter inasmuch as it dispenses with a great amount of machinery necesssry to the use of brine, and avoids the untidiness and loss of efficiency incident to the latter process, has never been a complete success in ice-making.

Although the use of brine in cooling or refrigerating plants has been done away with, experimenters have been unable to as yet devise a means whereby equally as good results can be secured without its use where water must be changed to its solid state.

This is owing primarily to the fact that in the freezing of water into ice, straight sur-

faces must be used, and all attempts that have been made as yet in the this direction have been partial or complete failures owing to the difficulty of constructing straight surfaces and keeping them tight while in use. The use of ammoniacal gas in wrought iron pipe answers the purposes admirably where cooling only is desired; but if a formation of ice is produced around the pipe, it can only be removed by the expenditure of considerable trouble and wastefulness; hence the necessity for straight surfaces.

Attempts have been made to imitate nature in the process of ice making by producing temperatures below the freezing point in well insulated rooms. But in these experiments the rooms were required to be excessively large on account of the low specific heat of air, and its low degree of conductibility, and even then the process of freezing was exceedingly slow.

Still another attempt at the production of artificial ice is a machine which freezes the water *in vacuo* without the aid of any agent other than the water itself. In this machine, the water being exposed to an almost perfect

vacuum is rapidly evaporated and this process of evaporation requiring a great amount of heat, which is furnished by the water itself. freezing occurs when the temperature of that portion of the water not vaporized is sufficiently lowered. The ice resulting from this process is, however, entirely unfit for market, being a mass of granulated snow, brittle and full of air, and quickly melted.

This latter precess was first proposed and experimented upon by E. Carre; and was afterwards used on an extended scale in Germany by F. Windhausen in his vacuum ice-machine. On account of the inferior quality of the ice, and because the sulphuric acid used to absorb the aqueous vapor, in connection with the air pump, caused considerable trouble in its process of reconcentration, this system was never a success.

The unsuccessful attempts at making ice without the aid of brine, induced experimentors to devote their energies to perfecting processes in which this undesirable article is used.

Although a great many systems of ice-making with the aid of brine have been devised, there are but three methods which have

established themselves in general favor and are extensively used. These are: The *Mould* or "*Can System*," the *Plate System*, and the *System of Stationary Cells.*

The System of Removable Cans.

This is the system most generally in use and its mode of operation is as follows: A well insulated iron or wooden tank is constructed, in which salt-brine is maintained at a very low temperature, considerably below the freezing point of water. The attainment of this low temperature, as has been explained, is secured by means of evaporting coils. Galvanized iron cans containing the water to be frozen, are immersed in this tank, the temperature of the surrounding brine being below the freezing point, it follows that ice will begin to form in the cans at their sides and bottoms, and the process of freezing will continue until the water in each can is converted into a solid block of ice. After the water is entirely changed to ice, the cans are lifted out of the tank, one by one, and submitted to a bath of tepid water; by which means the ice is loosened from them so as to be easily slipped out. After the removal of the ice, the cans are again filled with water, and immersed in the tank, when the freezing process begins anew. In this manner the process is continued without interruption, and permits of a regular output of the product day and night.

The Plate System.

By this system blocks of ice weighing one or more tons are produced, and the manner of procedure is to immerse a hollow plate of boiler-iron in a tank containing the water to be frozen, and filling the plate with brine. The manner of maintaining the brine at a temperature below the freezing point is similar to that of the can system; that is, it is accomplished by means of evaporating coils. In some instances the coils are placed in the plate, and in others in a seperate brine tank; the brine circulating from the tank to the plate and back again, thus maintaining an even temperature in both. In this manner ice forms on opposite sides of the plate, and when the freezing is continued for a suitable length of time, two blocks of ice will be the result. In order to remove this ice it is necessary to withdraw the cold brine from the plate, and in case the evaporating coils are placed therein, to suspend the circulation of ammonia in them. Tepid brine is now allowed to flow into the plate, and when its temper-

ature has risen sufficiently, the ice will cease to adhere to it, and may be hoisted out of the tank, and cut into blocks of suitable size. As a general thing several plates are immersed in each tank, and the freezing process allowed to continue in each plate at the same time, so that an entire tank may be emptied at once. When this is done, two or more tanks are necessary in order to make the output continuous, and while one is being emptied and refilled, the process of freezing is going on in the others. In very large plants quite a number of tanks are necessary in order to establish a regular output day and night. By the plate system the freezing is necessarily slow on account of the ice being formed from one side of the layer or block only. In the can system the freezing is going on from all sides at the same time, and continuing toward the center, and consequently if a block of ice produced by the plate system equals in thickness one produced by the can system, the length of time consumed in the first process will be four times that in the latter.

The System of Stationery Cells.

The cells used in this system have hollow walls and are open at the top. The fresh water to be frozen is placed in the cells, which are filled nearly to the tops. The cold brine is now pumped through the hollow walls, and the process of freezing goes on in a manner similar to that in the can system. After the blocks of ice are formed in the cells, the cold brine is pumped out, and tepid brine pumped in, so as to loosen the blocks and facilitate their removal. The freezing process in this system may be made as rapid as in the can system, by constructing the cells so that their width and depth will bear the same ratic to one another as do the dimentions of the cans in the latter system. But if the cells are made shallow, and of excessive width and length in order to make up the requisite capacity, the freezing will be necessarily slow on account of it occurring chiefly from one side only, that is, the bottom; and the time consumed in producing a cake of ice will quadruple the time consumed where cans are used.

Methods Employed to Produce Transparent Ice.

In the early stages of the ice-making industry, the quality of the article produced was lost sight of by many manufacturers, who regarded the fact of making ice as the only object to be attained. For this reason no special efforts were made towards obtaining transparent ice, until the demands of consumers for a better product brought this quality particularly to the notice of manufacturers. The first step in this direction was to freeze the water at a comparatively high temperature, but by this means only a portion of the block becomes clear, leaving an opaque core in the center; and the time occupied in freezing is excessively long. The cost of equipping a plant where this means is resorted to is also very excessive, on account of the large tanks and great number of cans required. In view of the disadvantages of this method efforts were made to devise a means of making the ice clearer, and at the same time freezing it faster and at a lower temperaturers.

A great many plans for accomplishing the production of transparent ice have been proposed, with varying success; and most of them are based upon the fact that if the water is agitated during the process of freezing clear ice will result. Among others proposed was a device for lifting a metal bar up and down in the can, and thus keeping the water in motion while freezing; another, to place a wooden paddle in the can and by some sort of arrangement keep it in motion; and still another, to insert a pipe into the can within a few inches of the bottom, and force a current of cold air through the pipe; the air would issue throngh perforations in the sides of the pipe and rise in bubbles to the surface, and in so doing would cause the water to circulate in the can. All of these arrangements answered very well, as far as making the ice clear was concerned; but this advantage was offset by the fact that to prevent them from being frozen fast in the ice-block, these devices had to be removed toward the end of the operation. Still another proposition was to rock the can in the tank, and thereby keep the water in motion. All of these different

methods, while attaining the desired result, had many objectionable features, and never found favor from a practical standpoint. In many instances the mechanism used in moving them was quite cumbersome, and when the process of freezing had been completed, and the cans were to be removed all this heavy apparatus had to be removed likewise.

The mode of making transparent ice, which has given the greatest satisfaction, and which is the one in general use to-day, is to deprive the water of air before placing it in the cans. The means of securing this result is by long continued boiling, or by exposing the water to a high vacuum, or by distillation under exclusion of the atmosphere. Exhaust steam from the engine, so far as it will supply the demand, is used to furnish the distilled water for filling the moulds.

This is to economize in fuel primarily; because there is a great saving where the steam is first utilized in the engine before going to the distilling apparatus. Before the exhaust steam can be used for purposes of ice-making, it must first be deprived of the oil which became mixed with it during its passage

through the cylinder, and this can be effectually accomplished by the use of steam filters of very simple construction. After being deprived of its oil, the steam is condensed and filtered in order to entirely deodorize it. After undergoing this purifying and cleansing process the resulting ice is as good as ice can possibly be made. On account of the water reabsorbing air during the process of freezing, there is usually a thin stratum of porous core in the center of the block; but notwithstanding, it is far superior to any natural ice that can be obtained.

The plate system, and the system of stationary cells, produce clear ice without resorting to any means for agitating the water, but the process of freezing is so slow, on account of being chiefly from one side only, that these methods have received but little favor.

Rating of Refrigerating and Ice-Making Machines.

These machines are susceptible of two ratings; that is, they may be rated by what is called *ice-making capacity*, or by what is styled *refrigerating capacity*.

In the former their capacity is stated in tons of ice they will produce in twenty-four hours; and in the latter, the rating determines the equivalent of the cooling work done by one ton of ice in melting in one day of twenty-four hours. These ratings apply to machines used for either purpose.

As a usual thing the ice-making capacity is taken at about one-half of the refrigerating capacity; but this estimate is only an approximation, since the tons of ice a machine will produce depends altogether upon the initial temperature of the water from which the ice is made, and other conditions.

The unit of measure in determining the capacity of a machine is one ton of ice frozen from water at a temperature of 32 degrees Fahr. into ice at 32 degrees, in one day; and

this is the equivalent of 284000 pounds of water reduced one degree of temperature or deprived of 284000 heat units, and is the basis for computing refrigerating tonnage capacity, as well as ice capacity when ice is produced from water at 32 degrees Fahr.

But the actual ice-making capacity of a machine must depend, as before stated, on the temperature of the water to be frozen, and can be calculated in the following manner: In melting one pound of ice into water at 32 degrees Fahr., 142 positive units of heat are absorbed, and consequently if water at 32 degrees be changed into ice, it follows that 142 units of negative heat will be required. Now if the water used for the purpose of ice making has an initial temperature of 92 degrees Fahr., as it frequently has in mid-summer when taken from the usual source of supply, such as a river, lake, or pond, it must be cooled to 32 degrees before freezing begins, and consequently $92° - 32° = 60° + 142° = 202°$; the number of heat units absorbed per pound of water frozen. As a general thing artificial ice is considerably below 32 degrees in temperature, for the rea-

son that the temperature of the brine in which it is produced is usually about 20 degrees below the freezing point, and this also must be considered in the work of freezing. By taking into account the specific heat of ice, this extra negative heat would be equivalent approximately to 10 heat units, which added to 202° = 212°, hence $\frac{142-10}{212}$ = 62 + per cent tons of ice manufactured per ton refrigerating capacity. This is only an approximation, and does not consider other contingencies such as losses by exposure of cans and ice tanks, the waste incident to the thawing out of moulds, etc. The ice-making capacity is calculated as a general thing at 60 per cent of the refrigerating capacity of the machine when working under favorable circumtances.

Mechanical Refrigeration in Breweries.

In the manufacture of lager beer, one of the first operations is the refrigeration of the hot beer wort, in order to prepare it for fermentation. The wort is first exposed to the air in a large shallow tank, enclosed by open lattice work, and the air circulating around the tank carries away considerable of the heat. It is then allowed to flow down over what is called a "Baudelot" cooler, consisting of two coils of pipe; through the upper one hydrant or well water is forced and the temperatnre of the wort reduced to about 60 degrees Fahrenheit; and the lower portion of the cooler is mechanically refrigerated by direct expansion of ammonia, by brine circulation, or by circulating ice water, and the wort is in turn reduced in temperature to about 40 degrees Fahrenheit.

In addition to the cooling of the wort, the refrigerating machine has another duty to perform in cooling and regulating the temperature of the beer during fermentation. Where ice is used for this purpose, it is accomplished

by means of cone shaped vessels made of tin or sheet copper, called "swimmers." In order to reduce the temperature of the beer in a fermenting tub, when in rises so high that fermentation proceeds too fast, one of these swimmers filled with ice, is placed therein, and allowed to float on the surface of the beer, which cools by contact with the cold surface.

With this device the temperature cannot be regulated with accuracy; the swimmers are very cumbersome and require considerable labor in handling; and their "drowning," or becoming completely submerged in the beer is of frequent occurrence.

On account of these defects swimmers have been replaced to a great extent by what are called "attemporators". These consist of coils of iron or copper pipe, placed in the tub, through which cold water is pumped at a temperature of about 34 degrees Fahrenheit. The water is cooled in a cistern or tank suitable arranged, provided with either a direct ammonia expansion or brine coil supplied by the refrigerating machine. The ice-water thus made is forced through the attemporators

in the tubs, and the pressure and amount required is automatically controlled by the attemperator pump and regulator.

Capacity of Machine for Work Required.

The table given herewith will be of advantage in the selection of a machine for purposes of refrigeration and ice-making; but it should be remembered that many other things have to be considered, such as climatic conditions, the manner of construetion and the exposure of the buildings to be refrigerated, the methods adopted in handling the work, etc.

All these things are best ascertained by an expert, who, from personal inspection of the premises, learns the precise conditions under which the plant is to be operated.

In making a selection of a machine it is advisable to take the allowances, in the following table, which give the largest margin of safety, as this provides for emergencies that that may arise, and also for increase of the business.

For each of the following duties, allow one ton refrigerating capacity per twenty-four hours.

BREWERIES.

Beer wort, 15 barrels cooled 70 degrees to 40 degrees.

Sweet Water, 900 gallons ice water cooled 40 degrees.

Cubic space, 6000 to 10000 cubic feet for entire brewery storage space.

PACKING HOUSES.

Hog chilling, 15 to 25 hogs of 250 pounds each.

Beef chilling, 5 to 7 beefs of 700 pounds each.

Calf chilling, 45 to 55 calves of 90 pounds each.

Sheep chilling. 55 to 70 sheep of 75 pounds each.

Storage space, 6000 to 12000 cubic feet per ton.

COLD-STORAGE WAREHOUSES.

Preserving rooms, 5000 to 8000 cubic feet space.

Freezing rooms, 3000 to 5000 cubic feet space.

By allowing 284000 heat units per ton refrigerating capacity each twenty-four hours, or 11833 heat units per hour, as a basis for calculations, much of the work to be done can be figured. A table of the specific heats of different substances is herewith annexed, to facilitate such calculations.

TABLE OF SPECIFIC HEAT.

Water at 32 degrees Fahr. equals one.

Cast iron	.130
Brass	.094
Mercury	.033
Tin	.056
Zinc	.095
Chalk	.215
Stone	.270
Masonry	.200
Oak wood	.570

Pine	.650
Glass	.197
Coal	.241
Sulphur	.202
Coke	.203
Alcohol	.659
Oil	.310
Vinegar	.920
Strong Brine	.700
Ice	.504
Water	1.000
Air	.238

In explanation of the above table, it is well to give the defination of *specific* heat. It is the *capacity* of a substance for absorbing heat, and is the amount of heat necessary to *raise or lower a substance one degree;* it being the ratio of the quantity required to raise or lower an *equal weight of water one degree.*

For example: One pound of water raised or lowered in temperature one degree Fahrenheit is called one thermal unit, and at 32 degrees, its specific heat is one. The amount of negative heat necessary to cool 100 pounds of water 10 degrees would be 100 pounds multiplied by one thermal unit multiplied by

ten degrees, which equal 1000 units. To cool 100 pounds of alcohol, 10 degrees Fahrenheit, as per above table would require 100 multiplied by .659 units multiplied by 10 equals 659 negative heat units. This latter as compared with the former shows that it requires but little more than three-fifths as many negative heat units to cool a certain quantity of a alcohol as it does an equal amount of water.

Water for use in Ice Factories.

Water for feeding boilers should be soft and deposit no sediment in the boiler. It is generally the case that water from sources far below the surface is not adapted for feeding boilers, on account of scale producing substances held in solution. When this is the case the boilers should be supplied from some other source, or if this can not be done, a system of filtering and purifying should be adopted, to expel from the water all deleterious substances.

It sometimes happens, for purposes of economy, that two kinds of water are used; for instance, in a city where water is paid for at a fixed rate, the boilers may be supplied from the mains, and this water after passing through the engine in the form of steam, goes into the ice moulds as distilled purified water.

The water for condensing purposes may be taken from artesian wells, from the sea. or from other sources of supply, where on account of its quality it is not suitable for feeding boilers. The two kinds of water may be

kept separate by suitably arranging the condensing and distilling apparatus.

The number of pounds of ice that can be produced per pound of fuel depends entirely upon the class of steam boiler employed, the nature of the fuel, etc. The exhaust steam from the engine, is not sufficient to supply the necessary amount of distilled water to fill the ice moulds, and the deficiency must be drawn direct from the boiler. The horizontal return tubular boiler is recommended.

The only known method to produce pure water, and whereby all deleterious acids, gases, and disease germs are eliminated and the water made perfectly hygienic, is by distillation.

The allowance of condensing water required for refrigerating machines is about one gallon per ton refrigerating capacity, and for ice plants from three and one-half to four gallons per ton, depending on the temperature of the water available.

Insulation of Buildings.

The proper insulation of buildings intended for the storing and preserving of substances subjected to refrigeration by mechanical means is a matter of the utmost importance when the economical management of the plant is taken into consideration.

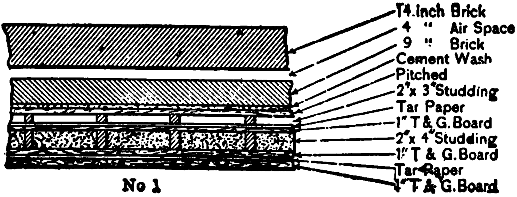
By employing refrigerating power greatly in excess of that otherwise required, it is true that errors of insulation, with the great loss of negative heat which is entailed thereby may be overcome, and the desired amount of cooling work performed; but this method would be expensive, and as the loss can be prevented otherwise and economically, it is a bad way to reach such a result.

A building is perfectly insulated when there is absolutely no transfer of heat through its walls; but this state of perfection is hardly possible. If it could be accomplished, the contents of the room being once cooled would suffice; because since there would be no loss, the temperature of the room and its contents would continue to remain the same indefinitely, and if all articles to be stored in

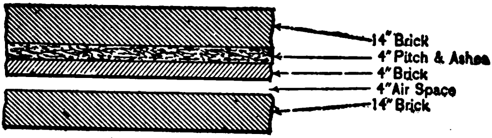
the room were previously cooled to the temperature prevailing therein, no refrigeration of the room itself would be required. In a great many instances a refrigerating machine is called upon to expend a large percentage of its actual work in overc oming the effect of the transfer of heat through the walls, floors and ceilings of buildings imperfectly insulated and this loss may be calculated by the use of suitable instruments.

It is found that difference in construction, exposure, and insulation of buildings, greatly effects the relative performance, as regards efficiency and economy, of machines of the same type in use in different localities; and the work performed by one machine and apparatus of a certain type is no standard for the duty of a similar machine in another place.

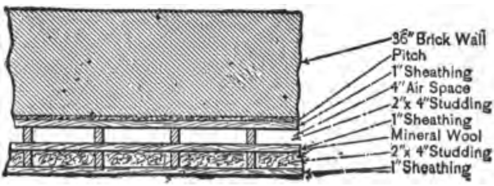
Figure 7 illustrates several plans for the insulation of buildings; all of which are to be commended, having been used with success. The table given herewith showing the comparative value of different insulating materials, will also be of advantage in making a selection. This table gives the conduct-



No 1



No 2



No 3

Fig. 7.

ing power for each square foot of surface of the materials, and the comparative value is expressed in the number of *units of heat lost* by transmission through them per hour. They are arranged in the order of their merit.

	Units Lost.
Copper	515.
Iron	233.
Zinc	225.
Marblein	28.
Stone	17.
Glass	7.
Brick work	5.
Plaster	4.
Double windows	3.6
Oak wood	1.7
Walnut wood	.8
Pine wood	.75
Saw dust	.55
India rubber	1.37
Brick dust	1.33
Coke dust	1.29
Cork	1.15
Chalk powder	.87
Charcoal powder	.64

Straw, chopped............	.56
Coal dust..................	.54
Hemp canvass.............	.41
Muslin......................	.40
Writing paper.............	.34
Cotton......................	.32
Air, confined..............	.3
Gray blotting paper........	.27

Tar paper, pitch, fine cinders, hair, felt, etc.. are used with success.

When constructing a building wherein low temperatures are to be maintained, one of the conditions to be taken into account is the liability of some of the above substances to absorb moisture from the atmosphere, and thus occasion decay, acid fermentation, and softening. For this reason it is well to select tar paper, well shellaced wood, pitch, granulated cork, or other substances that are impervious to the attacks of dampness. It should also be borne in mind that substances having strong odors are to be avoided, unless they are first deodorized.

Insulation No. 2, in Figure 7 is an example of one of the best constructions that can be used. In this the use of wood is entirely avoided.

The Management of an Ice Factory.

The operation of producing ice should be continuous, and the plant run day and night; this is necessary to secure the greatest possible production with the least expense. Besides this, the drawing of the ice should be done with regularity, a certain number of cans each hour throughout the day and night, and the drawing should be regulated so as to have it evenly distributed over the entire area of the tank. The machine should be maintained at a regular speed, and a uniformity of the steam pressure, water supply, boiler feed, and temperatures should be observed at all times. All these conditions are necessary in order to secure the best quality and greatest quantity of the product, with the least amount of labor and expense.

All parts of the apparatus should be kept clean, and in good repair. Everything about the distilling apparatus, ice cans and tanks should be kept absolutely free from dirt and impurities of all kinds. This can be accomplished by the use of a scrubbing brush, and harmless solvents, also by purging the distill-

ing system with steam, means being provided for this purpose. The charge in the filters should be changed as often as is necessary to ensure perfectly pure water.

The crew operating an ice-factory is usually divided into two watches, each for twelve hours. On a plant of medium capacity each watch would consist of one engineer, one oiler, one fireman, two tankmen, and one ice-house man.

The expenses incident to the operation of an ice-factory, are included in the cost of fuel, light, oil and waste; small repairs of various parts of the plant, loss of chemicals and the wages of engineer, fireman, and other employés.

Additional machinery, such as cooling pipes, etc., are required if cold storage rooms are used in connection with ice-making. In a case of this kind either the direct expansion or brine system may be adopted, and for the latter the capacity of the freezing tank may be increased by deepening the tank, and adding extra evaporating coils. A pump for circulating the brine should also be provided. In combined plants it is necessary to make

the "compression side" enough larger to take care of the additional work entailed by cold storage.

The same organization of skilled labor is required to operate a plant of a certain capacity as of one considerably larger; hence the expense in this respect is the same in either case.

The degree of efficiency and economy with which an ice plant can be operated depends to a great extent on the management, and care devoted to the business.